I

EVOLUTION OF THE GRAND CANYON DISTRICT[1]

THE Grand Canyon District is a lofty plateau in the southwestern portion of the United States, where the earth's crust is fractured and broken into gigantic blocks, some of them covered by majestic pine forests, others by the lowly cactus and sagebrush. Through it runs the gorge of the Colorado River, celebrated over the civilized world for the grandeur of its dimensions and the beauty of its coloring. Here everything is on a magnificent scale; cliffs a thousand feet high, canyons a mile in depth, volcanoes which reach to the clouds, and deserts which stretch to the horizon. We must learn to calculate elevations in thousands of feet, distances in hundreds of miles, time in millions of years, in this land of imposing altitudes, of vast extent, and of remote origin.

Let us begin our study by going back in time many millions of years. Imagine yourself, at that remote date, privileged to view the region we are about to explore. You would have before your eyes, not the level plateaus of limestone and sandstone of the present, but inconceivably ancient crystalline rocks, folded and contorted by mountain-building processes, upheaved to mountainous heights, and dissected by streams into mountainous topography (Fig. 1). There are volcanoes in this ancient land. Lavas break through the

[1] Public lecture delivered at the Rice Institute, March 13, 1934, by Douglas Johnson, Ph.D., D.Sc., Professor of Physiography in Columbia University.

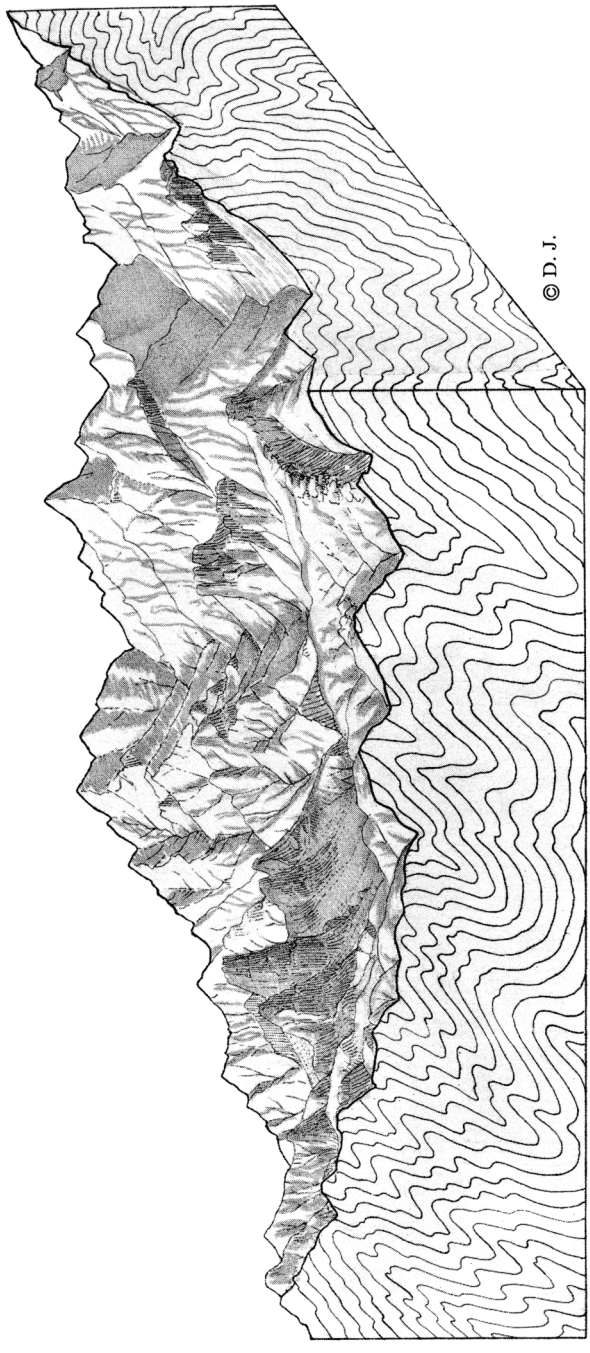


FIGURE 1. Complex mountains of the ancient Grand Canyon district.

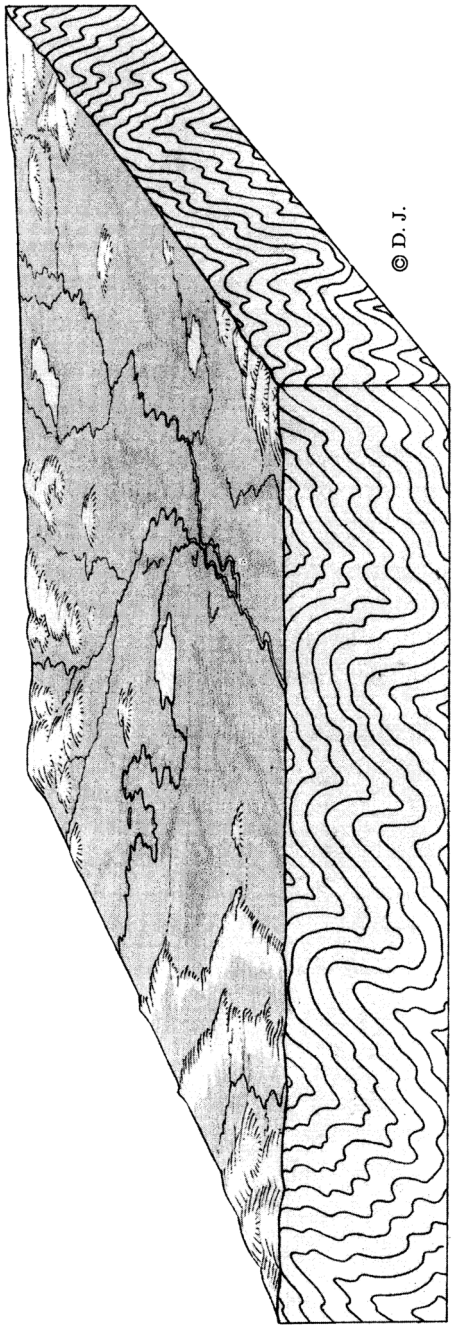


FIGURE 2. Long continued erosion has reduced the complex mountains of Figure 1 to a lowland of faint relief.

mountain flanks and stream down the valleys, while violent eruptions build volcanic cones of graceful symmetry.

Follow the course of the ages, and you will see the relentless power of water working its will upon the rock-ribbed hills. The rains descend, the floods come, and beat upon this land, and it slowly melts before our vision. The hills become lower and more rounded, the valleys wider and more evenly floored, as ceaselessly, through the millenniums, running water carries the mountains, particle by particle, into the depths of the sea. At last, when countless ages have unrolled their slow history before our eyes, we behold the mountains worn down to the level of the sea (Fig. 2), the limit below which rain and rivers cannot operate. The mountain scenery is gone, but the mountain structure remains. There is no longer any mountainous topography, but a vast lowland of erosion, bevelling across the roots of the mountain folds.

But even as we look, the scene changes yet again. The low land sinks beneath the ocean waters, and where the rivers flowed, the waves now roll in restless turbulence. Could we but see beneath the waters, we should find upon the old land area, now transformed to sea-bottom, layer after layer of muds and sands accumulating, to form the rocks of a later age. From time to time the accumulating series may be raised to the surface, and the formation of marine sediments give place to the deposition of land débris (Fig. 3). Countless millenniums pass, till more than ten thousand feet of horizontal layers bury the old eroded mountain structure, when the combined mass is raised high above sea-level, with a strong tilt toward the east (Fig. 4).

Once more we trace the history of this newly uplifted land mass through the unending succession of centuries. We watch the rivers cut deep into the rocks, and carve them

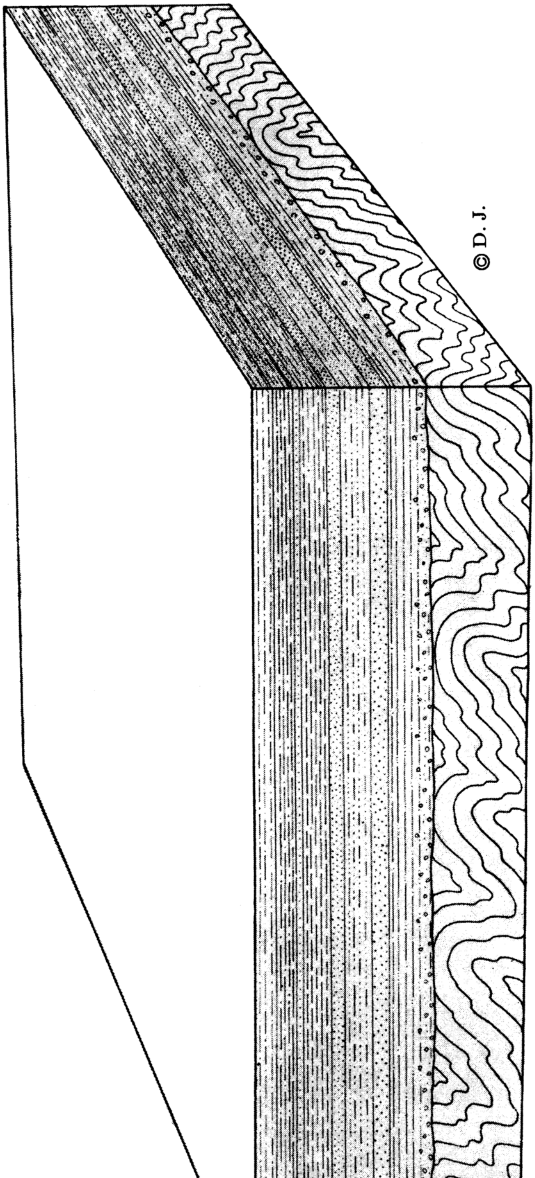


FIGURE 3. More than 10,000 feet of sediments are deposited on the old erosion surface of Figure 2.

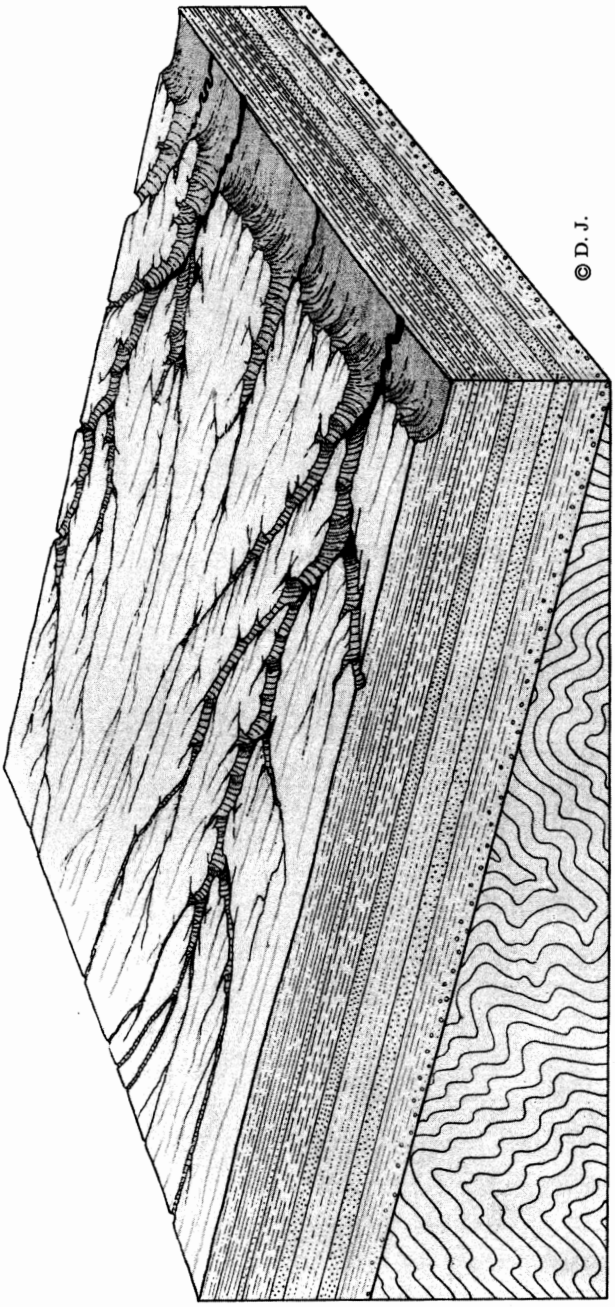


FIGURE 4. The land mass represented in Figure 3 is uplifted with a strong tilt to the east.

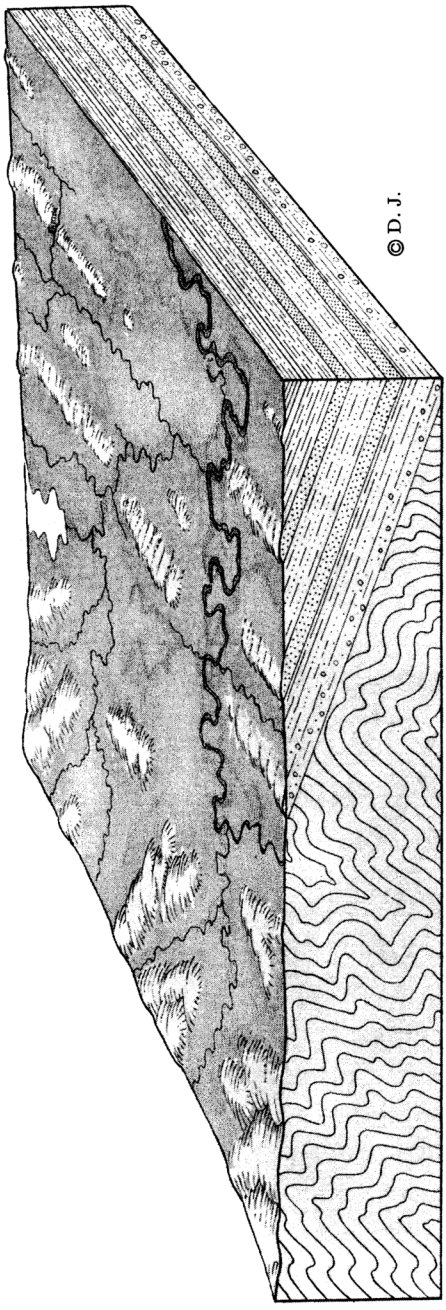


FIGURE 5. A second period of prolonged erosion reduces the tilted mass of Figure 4 to a second lowland of faint relief.

into rugged mountain shapes. We see the mountains wear slowly down under the never-tiring forces of erosion. And we see the valleys open wider, and ever wider, to consume the intervening hills, until once more the entire mass is worn down to a second lowland of erosion (Fig. 5). Because the mass was strongly tilted, this new erosion surface bevels across the more ancient mountain folds in the western part of the region, and in the east across the series of stratified rocks. Thus was formed a wedge of the stratified series which we must note most carefully, for we shall find it again some millions of years later, when we journey together across the country of the Grand Canyon.

Let us resume our vigil through the geologic ages. The new erosion surface sinks slowly into the sea, and again there are deposited upon it layers of sand, silt, and lime muds (Fig. 6) to a thickness which would be incredible did we not realize that as the deposits accumulate the bottom continues to sink, thus constantly making room for more accumulations at the top of the series. There were periods of uplift, with erosion of the exposed sea-bottom deposits and deposition of land débris. At the end of a time so vast that the mind could not grasp the number of years even could we name them, a total thickness of more than sixteen thousand feet—three miles—of horizontal layers of sandstone, shale, and limestone had accumulated on the old erosion surface.

And now again there is a great uplift (Fig. 7) which transforms the deposits into a high land mass. Again the uplift is greater toward the west than toward the east. But this time, instead of uniform tilting, the uplift takes the form of gigantic steps, each from one to several thousand feet high and many miles broad, descending from the high western land to the lower eastern region. At the edge of each step the rocks bend gracefully downward to the step

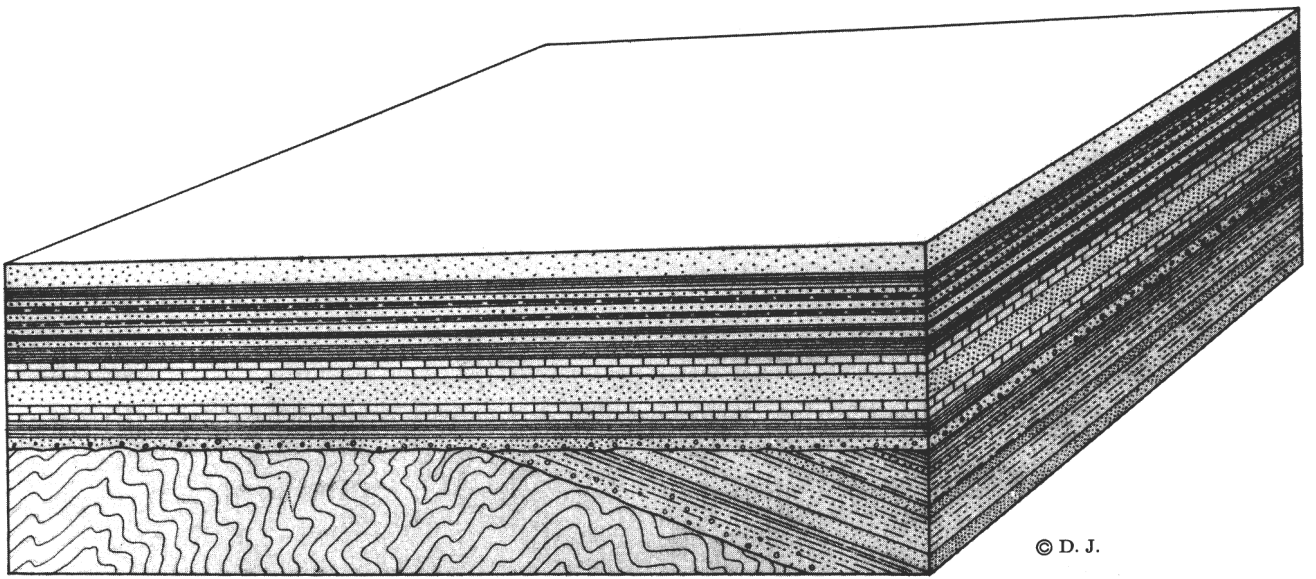


FIGURE 6. Renewed deposition of sediments buries the old erosion surface of Figure 5 under more than 16,000 feet of sand, silt, and lime muds.

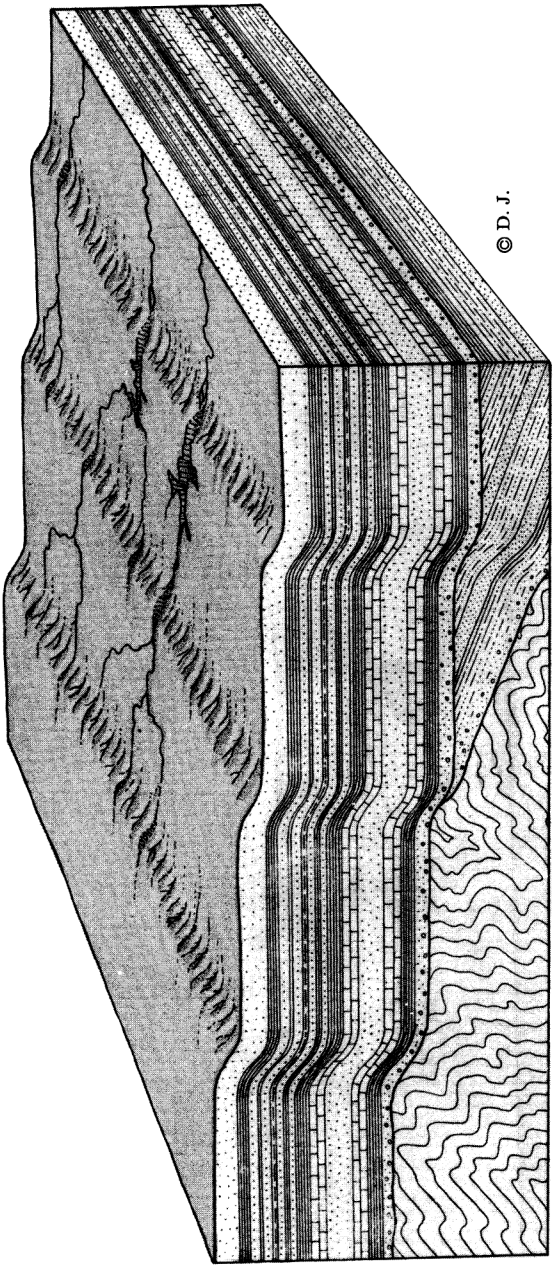


FIGURE 7. The land mass represented in Figure 6 is uplifted and warped to form a series of giant steps, highest at the west.

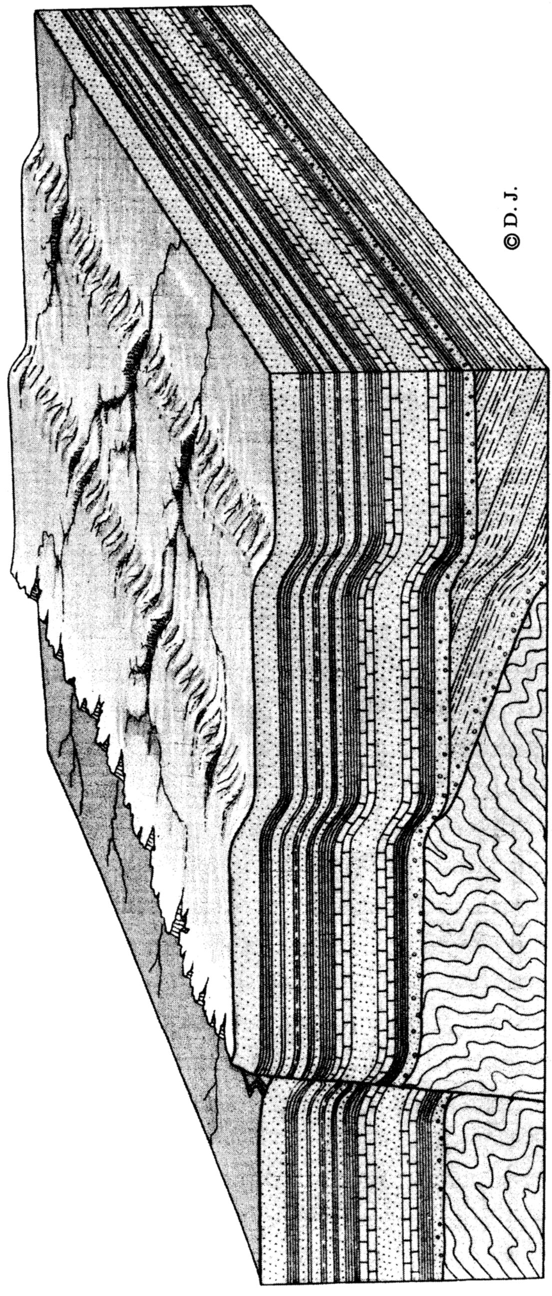


FIGURE 8. Fracturing of the earth's crust along some of the warps or bends represented in Figure 7 permits a downdropping of the land at the west.

below, for in this case the forces of elevation did not shatter or break the thick deposits.

But now there comes a great change. The land at the west, which was raised highest, is now dropped lowest (Fig. 8). The two eastern steps of the earlier series remain unchanged; but westward a total of five other steps, only one of which is shown at the left of the diagram, suffer a complete reversal of topography. At each former bend, perhaps because the rocks are weakest there, the mass is broken by a nearly vertical fracture, and the block to the west is dropped downward from one to several thousand feet. Thus there develops a new series of giant steps leading downward to the west, while the two ascending steps at the east remain intact. Later we shall see all of these steps; but for the moment we will keep to the limits of our diagram, and understand that this western step, and its break or fracture, represents four others of similar character.

Now for the third time watch patiently through vast ages of slow erosion, and see the bent and broken mass worn gradually down to sea-level (Fig. 9). The giant steps, the down-bent slopes on the east, the steep fracture scarps on the west, all disappear, and in their place we see a new and third erosion plane, bevelling across the rocky structure. Only far to the northward the erosion process is incomplete, and hard layers of rock project to form a series of erosion cliffs, each from several hundred to a thousand feet in height. These are not straight and simple like the cliffs due to bending or breaking of the rock layers, but are irregular, due to the unequal headward gnawing of different streams cutting back into the cliffs. South of these erosion terraces, however, the region is as low and monotonous as are most lands which have been worn nearly to sea-level by prolonged erosion. Here and there a volcano has erupted, and from

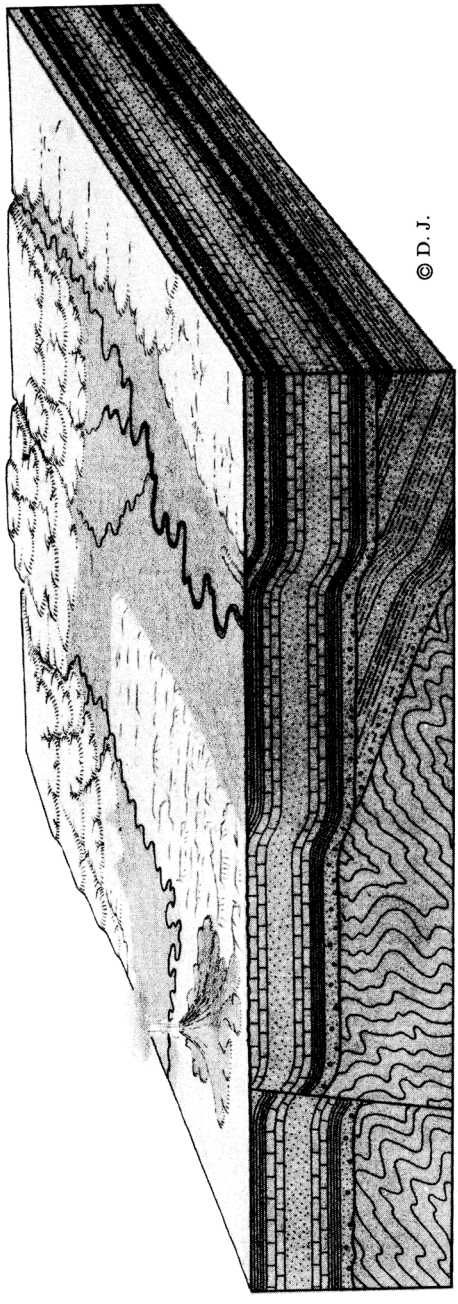


FIGURE 9. A third period of prolonged erosion reduces the bent and broken land mass of Figure 8 to a third lowland of faint relief.

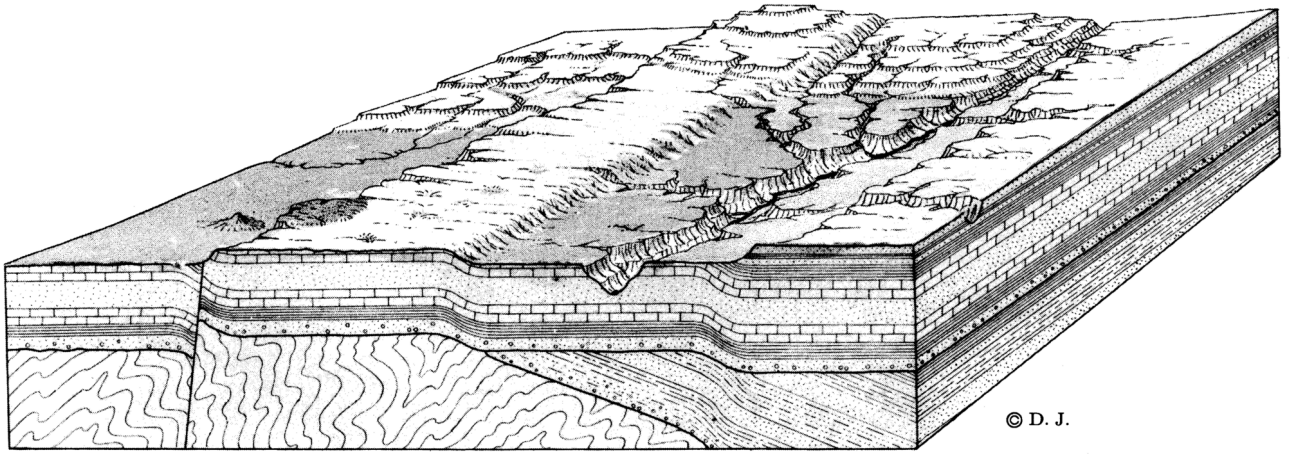


FIGURE 10. The land mass of Figure 9 is lifted high above sea-level, canyons are cut, and cliffs developed by the renewed erosion. See also Figure 11.

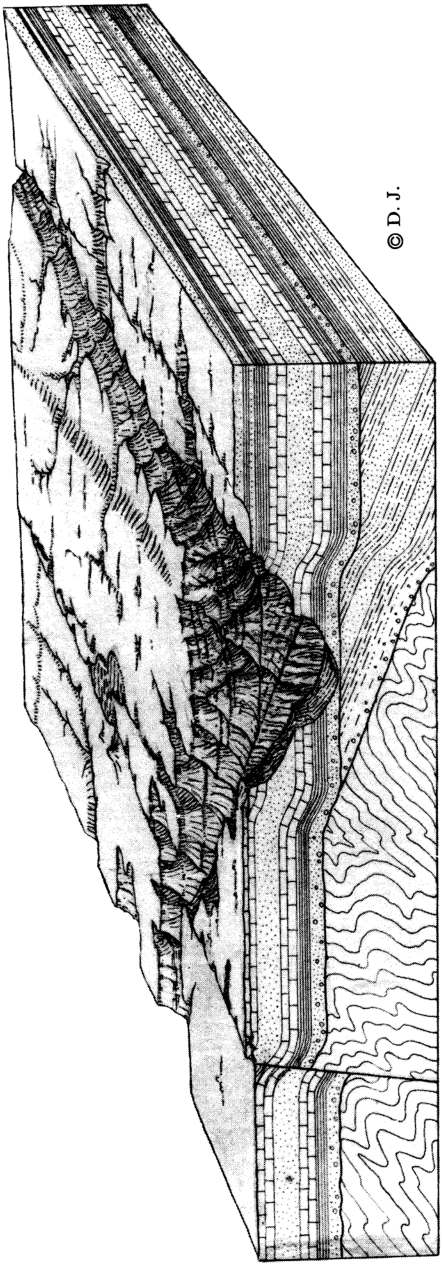
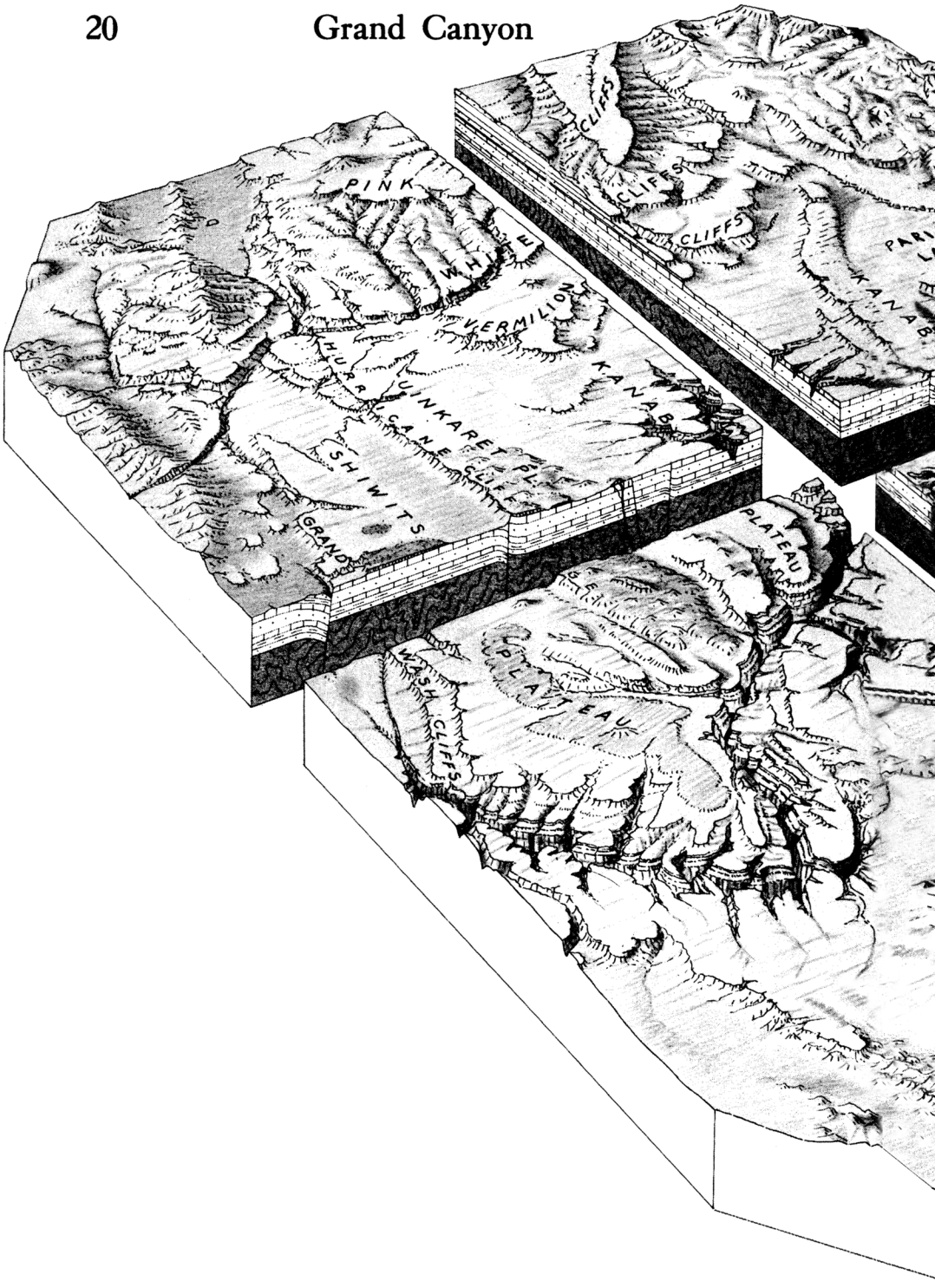


FIGURE 11. Diagrammatic view of a portion of the Grand Canyon district south of Figure 10, showing the two older erosion surfaces and the associated wedge of inclined rocks exposed in the canyon walls.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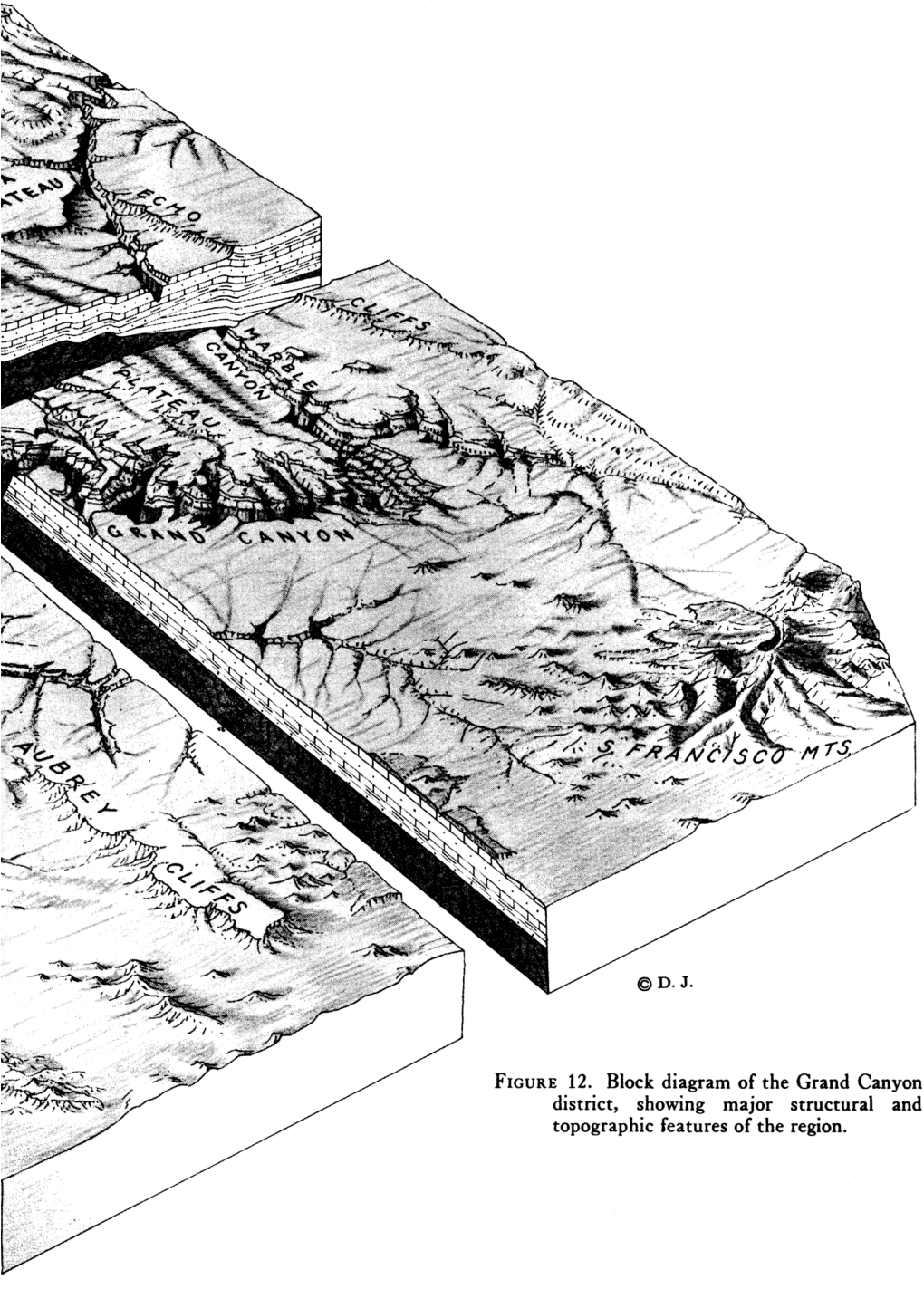

FIGURE 12. Block diagram of the Grand Canyon district, showing major structural and topographic features of the region.

the cone lava flows may spread directly across the fracture line, so nearly level is the surface on the two sides. Rivers wander in sluggish courses over the low land, especially where belts of weak shales are exposed, awaiting a fate which may be extinction if the land sinks into the sea as we have watched it do twice before; or may be rejuvenation and a new life history, if uplift permits the stream to begin again the process of erosion.

This time it is uplift which supervenes. Let us observe (Fig. 10) the consequences of the new elevation and of the renewed erosion. The main stream is entrenched in a canyon. The weak shales are stripped away from the two belts where they were exposed, thus developing lower plateau levels on the more resistant limestone. There is a line of west-facing cliffs along the fracture plane; an east-facing slope, in the center, where the bent limestone is exposed; and a west-facing scarp where the sandstone cap rises over the lower country left by removal of the shales. Off to the north are the erosion terraces, where the agents of denudation failed to wear the land as low as they did farther south. In the front edge of this ideal block of the earth's crust we see the two oldest erosion planes, the ancient mountain mass of contorted crystalline rocks, and the wedge of tilted, stratified rocks, all somewhat bent or broken by the earth movements whose history we have already traced.

In Figure 11 we have before us an epitome of the evolution of the Grand Canyon District, and a diagrammatic explanation of the origin of its grandest scenic features. The old mountain mass of hard crystalline rocks, the wedge of inclined weaker sediments, and the two erosion planes associated with them, will prove keys to the scenery at the very bottom of the Grand Canyon; the horizontal layers of sandstone, shale, and limestone will give the superb architec-

tural effects of the upper Canyon walls; while the plateau above is famous for its imposing cliffs, developed along lines of folding and fracture, or by irregular erosion of the higher plateau terraces farther north.

With this history fresh in our minds, let us select the best routes for our journey across the geological wonderland made famous by the early explorations of Powell, and the classic writings of Dutton. In Figure 12 one may trace the course of the Colorado River in its deep canyon, and observe that the plateau which it trenches is broken into blocks by rudely parallel lines of cliffs trending more or less north-south, while across the northern end of the district are more irregular cliffs which roughly approximate an east-west direction. Since the cliffs related to lines of folding and fracturing trend nearly north-south, and split the plateau into successive blocks separated by imposing escarpments, if we start at the eastern margin of the region and travel westward we shall have the best opportunity to observe the scenic effects of the great displacements of the rocks. On the other hand, if we start at the south and travel northward, keeping between the fracture lines, so as not to cross them, we can best study the scenery of the unbroken parts of the plateau surface, the depths of the canyon, and the great erosion terraces at the north. Each route has its peculiar advantages, and we shall take them both.

Let us then commence our journey from east to west, directly across the fractures and folds, and the blocks into which they divide the plateau. For the purpose we have light mountain wagons to carry our camp equipment. The beds are mere rolls of blankets, and we sleep on the ground, under a clear sky, for in this arid country it seldom rains. We cook our meals on a little iron frame set over the camp-fire,

and eat them under the shelter of a piece of canvas stretched from the wagon to protect us from the glaring sun; for even in the shade the thermometer will register 116° Fahrenheit. To carry drinking water we have two wooden casks; but to supply them we shall find only water that is usually warm and often alkaline. But what are trifling hardships like these, when we are about to discover the origin of such remarkable scenic features as those of the Grand Canyon District?

We camp for the first night near the base of the Echo Cliffs, the easternmost escarpment, which faces westward toward a lower plateau produced by removal of a broad belt of weak shales. It is sunset, and in the foreground the soft, dark shales below the sandstone are in shadow; but the red and pink sandstones above them glow brightly in the last light of the closing day. The scarp is nearly a thousand feet high, barren of vegetation, and forms a wall stretching scores of miles along the eastern border of the Grand Canyon District.

For years I had read on maps the words "Echo Cliffs," and it was to me no more than a name of a certain topographic feature. But one night, as we drove along in darkness to escape the heat of day, and my thoughts dwelt on the great scarp dimly visible in the starlight, it suddenly occurred to me that the name itself had a meaning, and that the Echo Cliffs might indeed be noted for the excellence of the echo they produced. Drawing my gun, I fired a shot into the darkness. The report was followed by a moment of silence; then, suddenly, from in front, the cliffs gave back the crash; roar on roar, peal on peal of thunder, magnified as in a mighty tempest, and rolling farther and farther away to the north and to the south, as each rocky ravine, each recess in the lofty wall, sent back its particular echo to be

confounded in one colossal wave of sound. Never had I heard an echo so wonderful; and from that night the name "Echo Cliffs" has had for me a new significance.

The desert floor (Fig. 13) in front of the Cliffs is exceedingly barren. We have great difficulty in finding enough grass for our horses, and since if we tie them at night they will soon consume the few mouthfuls within reach of their tether, we must let them wander loose, yet keep guard over them lest they stray too far and leave us stranded in the midst of the desert. If anyone desires a few hours of tranquillity, in which to meditate without distraction upon the sins of his past, I recommend night-herding horses in the midst of the Arizona desert, several miles from camp and many miles from the nearest human habitation, with the stars the only light in the darkness, and the howl of the coyote the only sound to break the oppressive silence.

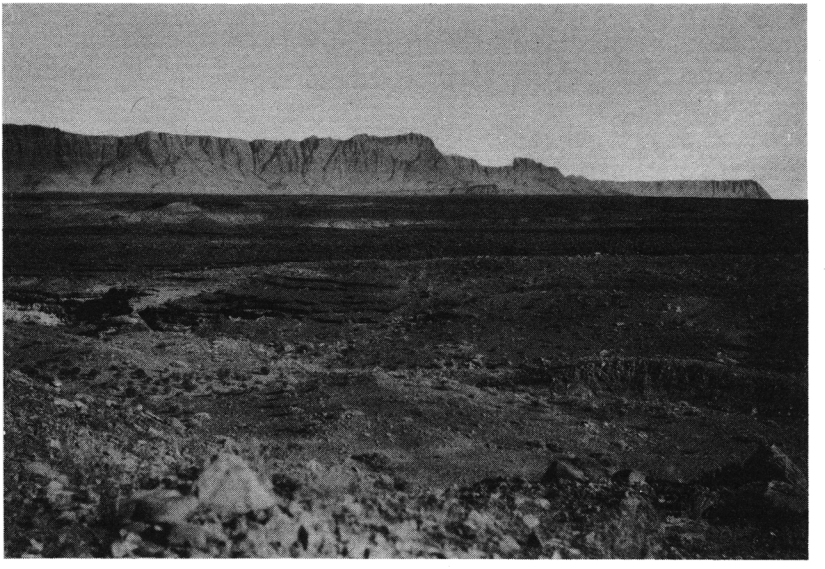

FIGURE 13. Barren surface of Marble Platform in front of the Echo Cliffs, looking northwest toward Vermilion Cliffs.

Crossing the level floor of the plateau block known as the Marble Platform and approaching its western edge (Fig. 14) we observe that the limestone layers over which we have been traveling begin to arch gently upward, toward the west, in the first part of the great fold which leads two thousand feet higher to the elevated Kaibab block. The grey rock and the scanty grey desert vegetation still give a barren scene, in which the geological structure is the more clearly revealed. In places the fold is more sharply developed, and the ascent from the lower to the higher level is made with great difficulty. Let us make the ascent of the steep fold and reach the forested highland of the Kaibab plateau block (Fig. 15).

Could there exist a contrast more striking than that between the burning desert we left two thousand feet below us, and this upland forest of pine with its cooling shades?

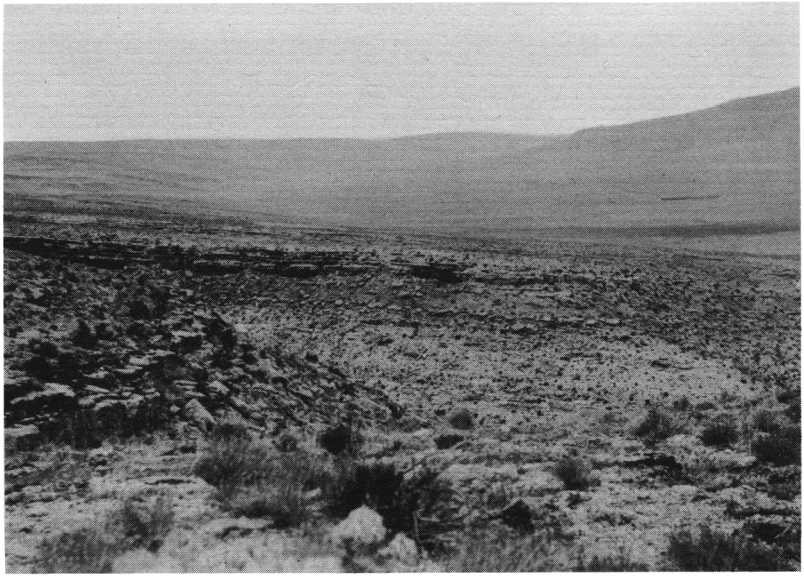

FIGURE 14. Limestone layers of Marble Platform arching up toward west (left) to form the high Kaibab plateau block.

FIGURE 15. Typical pine forest of the higher plateaus, Grand Canyon district.

Here we pause for a day to rest our horses, to let them browse on the more abundant grass, and drink the water accumulated in limestone sinks. Then, pushing onward through the pines, we begin the western descent (Fig. 16), where a small valley has cut back into the high block from the face of the cliffs marking the western fracture. We might regret leaving this wooded paradise for the desert of the Kanab block below us to the west, but for the fact that the lure of the unknown beckons us, and we are eager to see the great fracture cliffs of which we have heard, but which to us personally are as yet *terra incognita.*

We emerge at last from the Kaibab block, and turning back, see the mouth of the valley cut in the face of the scarp which bounds it on the west. We have descended to the level of the cedars and junipers, and a little farther west find ourselves on the sagebrush-covered surface of the Kanab block (Fig. 17). Looking backward once more we have a

final view of the high Kaibab block, with its level surface forming the even skyline of the eastern horizon.

As we continue our westward journey, we are amazed at the levelness of the Kanab plateau block. Branches of the Grand Canyon have cut back into it in places, but over broad areas the limestone surface seems as smooth as if the weak overlying shales had been stripped off but yesterday. At length we cross the Sevier fracture where it is about to disappear, and reach the Toroweap fracture. Here it is merely a bend in the limestone beds, with a displacement of but fifty or a hundred feet; but farther south (Fig. 18) it has very imposing dimensions. For miles it stretches from north to south in a nearly straight line, a scenic feature of real grandeur rising nearly a thousand feet above the lower land to the west.

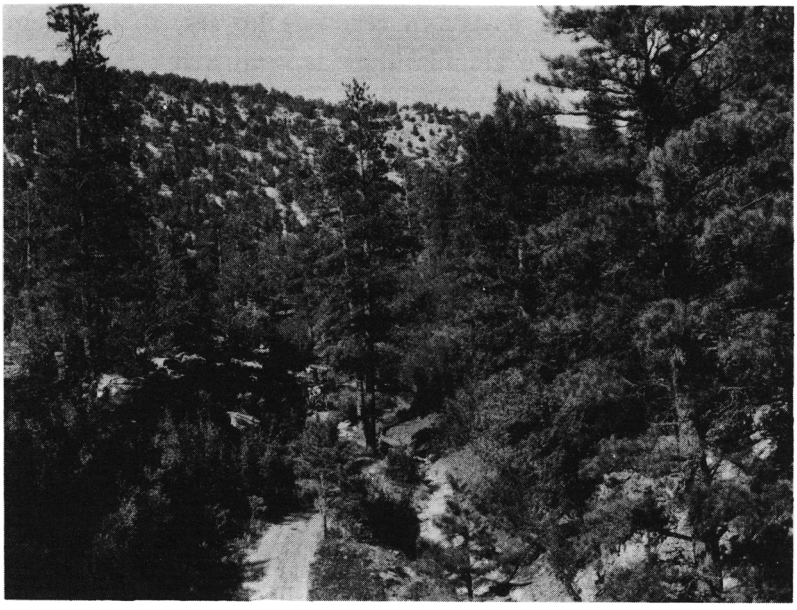

FIGURE 16. Jacob's Canyon, cut back into western edge of Kaibab plateau block.

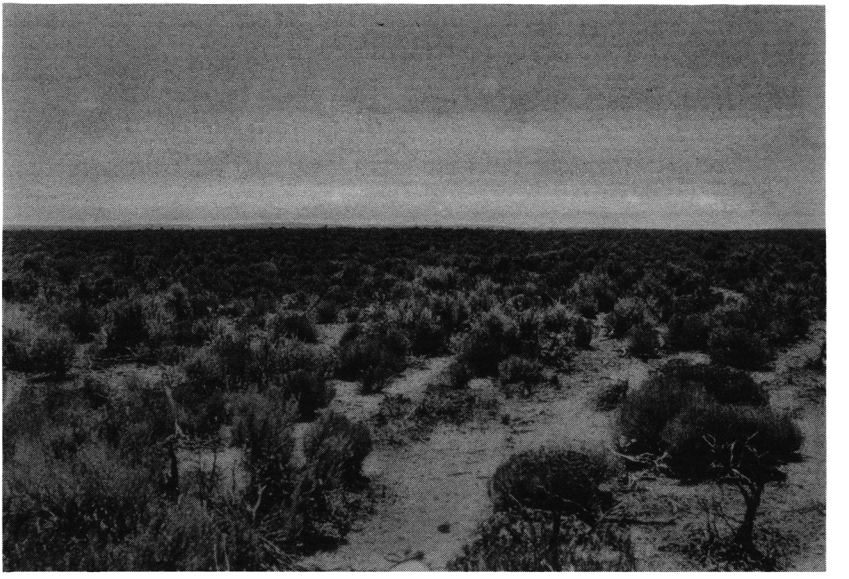

FIGURE 17. Sagebrush-covered surface of the Kanab plateau block.

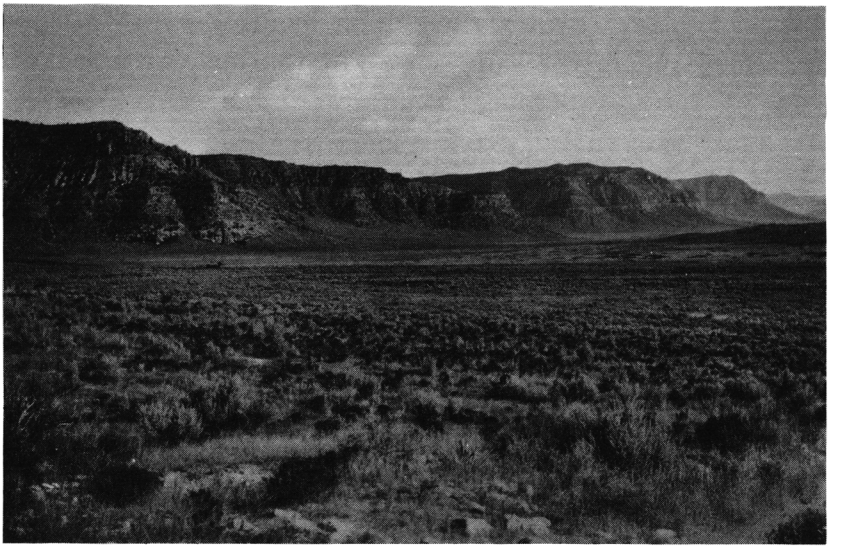

FIGURE 18. Toroweap fault-line scarp, marking one of the fractures which divide the plateau into blocks.

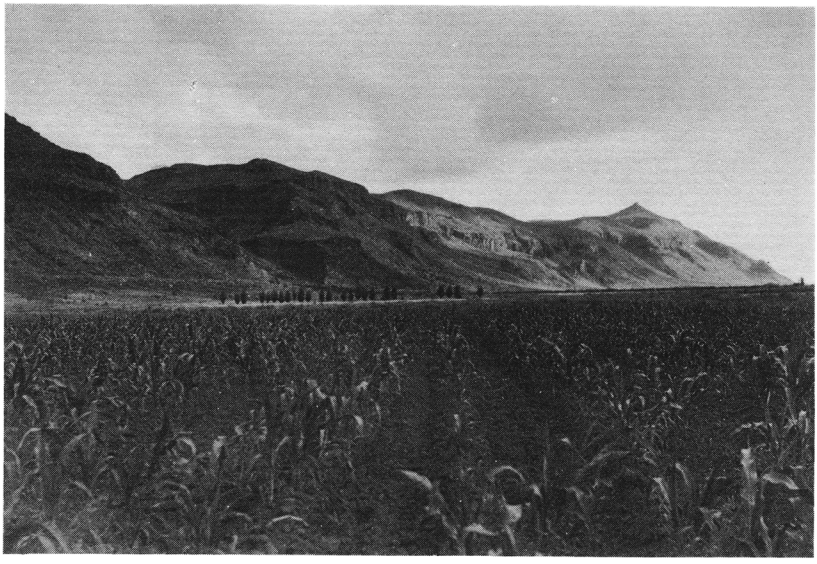

FIGURE 19. Hurricane Ledge, a major escarpment marking a fracture over 200 miles in length.

This is one of the wildest parts of the Grand Canyon District. We see coyotes running in bands of six or eight together, and in three days we kill fourteen rattlesnakes. Grass is fairly abundant, but springs and streams are rare. We make the usual dry camp; and after a vain hunt up and down the valley for a place to replenish our casks, are content to lie flat on our stomachs, and, using a handkerchief as a strainer, suck from a muddy slough the brown liquid accumulated in the footprints of cattle. At night as we lie about the camp-fire of burning sagebrush, watch the flickering light play weirdly on cliff face and lava flow, and hear the coyotes howl from the slopes of a volcano across the valley, we feel that in all truth we have entered a nether world which only a Dante could paint in fitting words.

On westward we journey across the level surface of the Uinkaret desert, often with small volcanoes or lava-capped

mesas visible on the southern horizon, till finally we reach the famous Hurricane Ledge fracture (Fig. 19). In one of the valleys cut back in its face we can actually observe the displacement of the rocks, with the grey limestones of the upper Uinkaret block on the east, while to the west the much higher beds of shale and sandstone are dropped down thousands of feet from their former position, and dragged into a vertical position by friction along the fracture plane.

Looking against the cliff from the surface of the lower Shivwits block one sees a very peculiar phenomenon; a thin strip of volcanic lava adhering to the scarp (Fig. 20). It is not the exposed edge of a layer of lava included between the limestone layers, but a mere film of lava plastered on the cliff face far above its base. Under foot the observer finds that there is similar lava forming a sheet covering part of the Shivwits block; and he realizes that the two were once

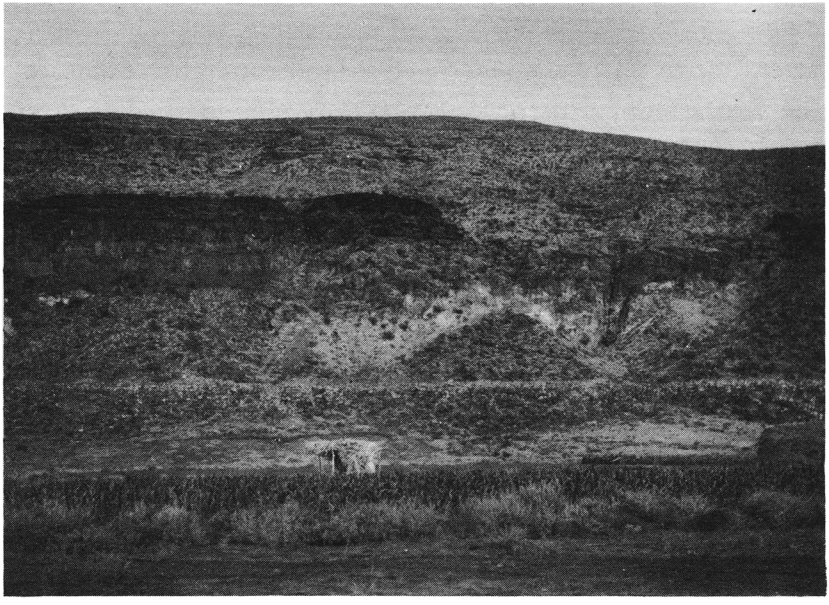

FIGURE 20. Strip of dark colored lava adhering to face of grey limestone cliff. Hurricane Ledge, south of Virgin River.

continuous. Before the Shivwits block had been dropped down so low, a volcano erupted lava on its surface, which flowed eastward until stopped by what was then the base of the scarp. Further displacement along the fracture dropped the Shivwits block and its lava cover still lower; but a thin strip of the lava stuck to the face of the limestone in its original position. Thus it appears that the displacement did not take place at a single stroke, but was intermittent in its action. When the geologist takes account of these facts, and considers the erosion records which streams have cut in the different rock layers, he is able to unravel the very complicated history of this remarkable line of cliffs. He then discovers that there were three distinct periods when this part of the earth's crust was dropped down, lower and lower, these periods of movement along the fracture plane being separated by periods of erosion and of volcanic activity. Does not the scenery of these desert cliffs take on a new significance, when we find it possible, by giving careful attention to each element of the landscape, to reconstruct the evolutionary history of the region, and thus to carry ourselves backward not merely hundreds of thousands, but millions of years in time, to the scenery of a long lost geological epoch?

The Hurricane Ledge is a rock wall which can be traced for more than two hundred miles from south to north across Arizona and Utah. We could with profit follow this scarp on its northward course, or journey westward over the Shivwits block to the Grand Wash Cliffs; but time flies, and we can more profitably begin at once our journey from south to north (Fig. 12), on which journey we are to avoid the fracture lines but study the Grand Canyon and the succession of erosion terraces on the northern border of the district.

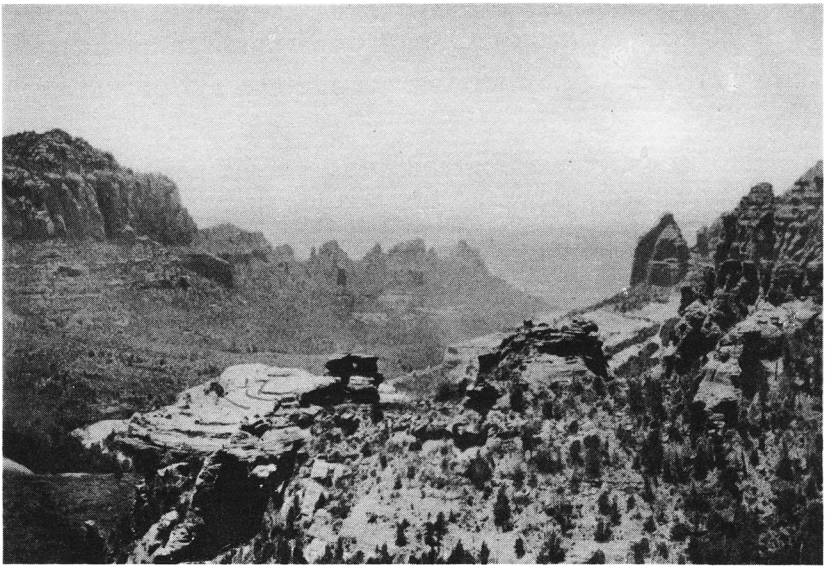

FIGURE 21. Bear Wallow Gulch, Arizona, showing castellated rocks at southern edge of the Grand Canyon district.

We start our northward journey below the southern edge of the plateau region, in the depressed level of the Great Basin. Our first task is to negotiate the three thousand feet of steep ascent to the high surface of the plateau. For this purpose we follow up one of the numberless ravines which dissect the plateau margin, and in which the castellated walls of horizontal red rock give a picture we cannot soon forget (Fig. 21). Looking backward we see the low Basin region with its isolated mountain ranges. Before we reach the upland we catch a glimpse of Oak Creek Valley, eroded on one of the north-south fractures. We avoid crossing this fracture line, and reach the plateau surface to the east of it.

It is a relief, after the long and tiresome ascent, to traverse the level upland with its stately forests of yellow pine, and to rest for a time in the shade which is seldom found in the Great Basin below. Usually our course is un-

obstructed by any natural barrier, but occasionally the northward route must deflect around some minor canyon head. We stop for a day to examine the famous cliff dwellings in Walnut Canyon (Fig. 22), where a race of unknown antiquity took advantage of the overhanging limestone ledges to construct their homes in this inaccessible spot. Farther north we camp at the base of the majestic San Francisco volcano, towering six or seven thousand feet above the surface of the plateau, itself six thousand feet above sea level. The volcano is extinct, and streams have deeply scored its sides. If we toil upward through the forests, and emerge above the timber line, we may reach the summit (Fig. 23) almost thirteen thousand feet high, and study there the work of an ancient glacier which hollowed out a cirque or amphitheatre at this high altitude. Fire and water, ice and wind, have

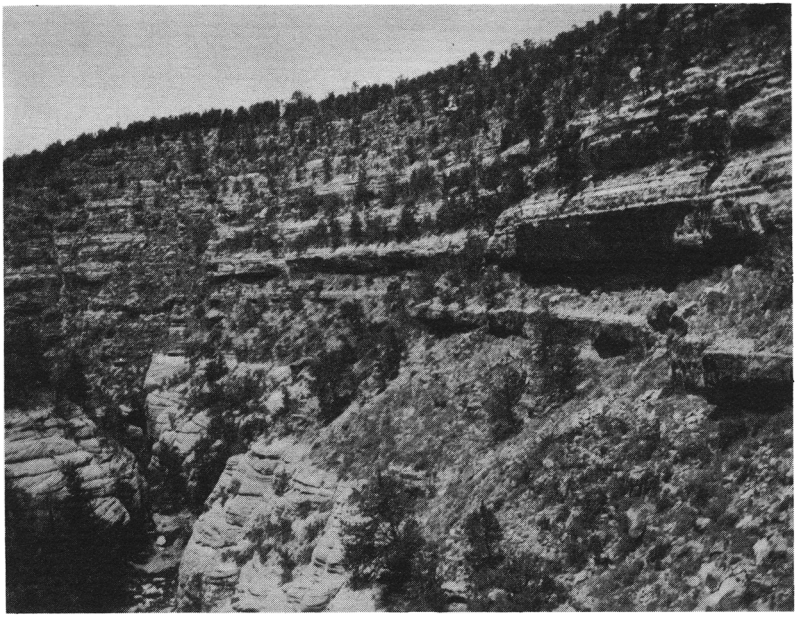

FIGURE 22. Walnut Canyon, showing overhanging limestone ledges which shelter cliff dwellings, with narrower gorge in resistant sandstone below.

FIGURE 23. Summit portion of San Francisco volcano, showing part of cirque excavated by local glacier. The snowbanks (picture taken in July) are most abundant in the cirque.

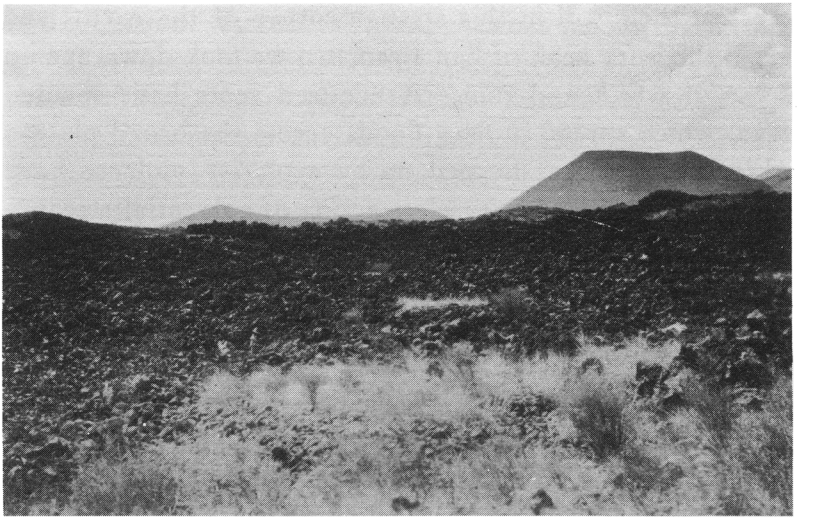

FIGURE 24. Recent volcano and lava flow. One of many small volcanic vents surrounding the main volcano shown in Figure 23.

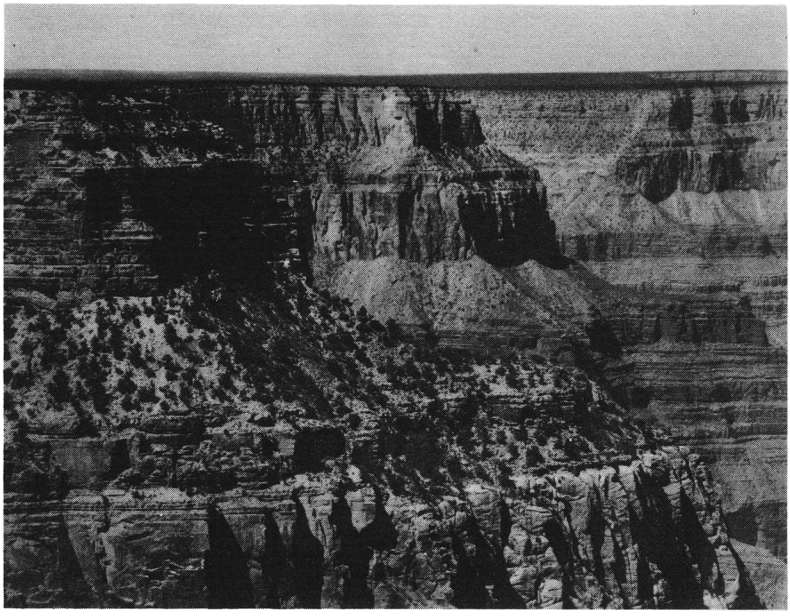

FIGURE 25. Brink of the Grand Canyon, looking west from Hopi Point.

worked their will in this strange corner of the earth; and from the lofty peak of San Francisco we look down upon a scene of wreck and ruin. A hundred vents have spouted lava, which spread in fiery floods across the broad plateau (Fig. 24). Cones heaped up by explosive violence have been cut to pieces by ceaseless action of torrential streams. The very heart of the highest mountain has been eaten out by the gnawing glacier; and over all the wind has drifted volcanic ash and dust.

From the snows of the volcano's summit to the depths of the Grand Canyon we are to descend some eleven thousand feet in two days. Approaching the Canyon rim, we remark how sharply it is cut into the level surface. Looking (Fig. 25) over the brink, we see below us the horizontal limestones exposed in nearly vertical walls, giving some hint of

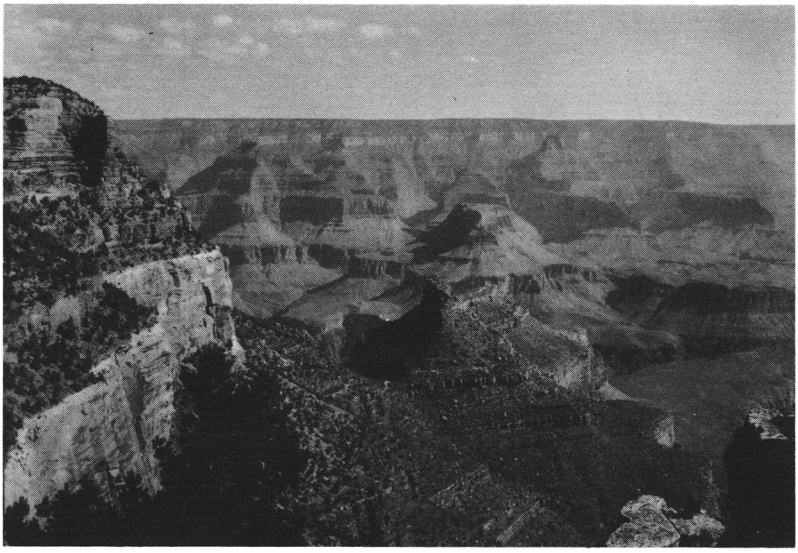

FIGURE 26. View northward from near Maricopa Point, showing general character of architectural forms of Canyon walls.

the architectural forms which are to delight us a little lower in the Canyon. Across the great chasm is the northern wall, and if we look carefully we may see, fifteen miles away to the northwest, one of those fracture lines which so greatly interested us on our east-west journey. We may even see the rock layers bending down toward the fracture, and will realize that this represents one of the early bends or folds which preceded the breaking. Evidently the fracture proved a line of weakness which streams easily discovered, for a side canyon is being eroded along its course.

A little lower in the main canyon (Fig. 26), there come into view the architectural forms to which we have alluded. Between the labyrinthine ramifications of side streams, the remains of the plateau take on a thousand fantastic forms: spurs, peninsulas, islands, mesas, buttes, eroded into ragged contours with infinite variety of outline. The alternation

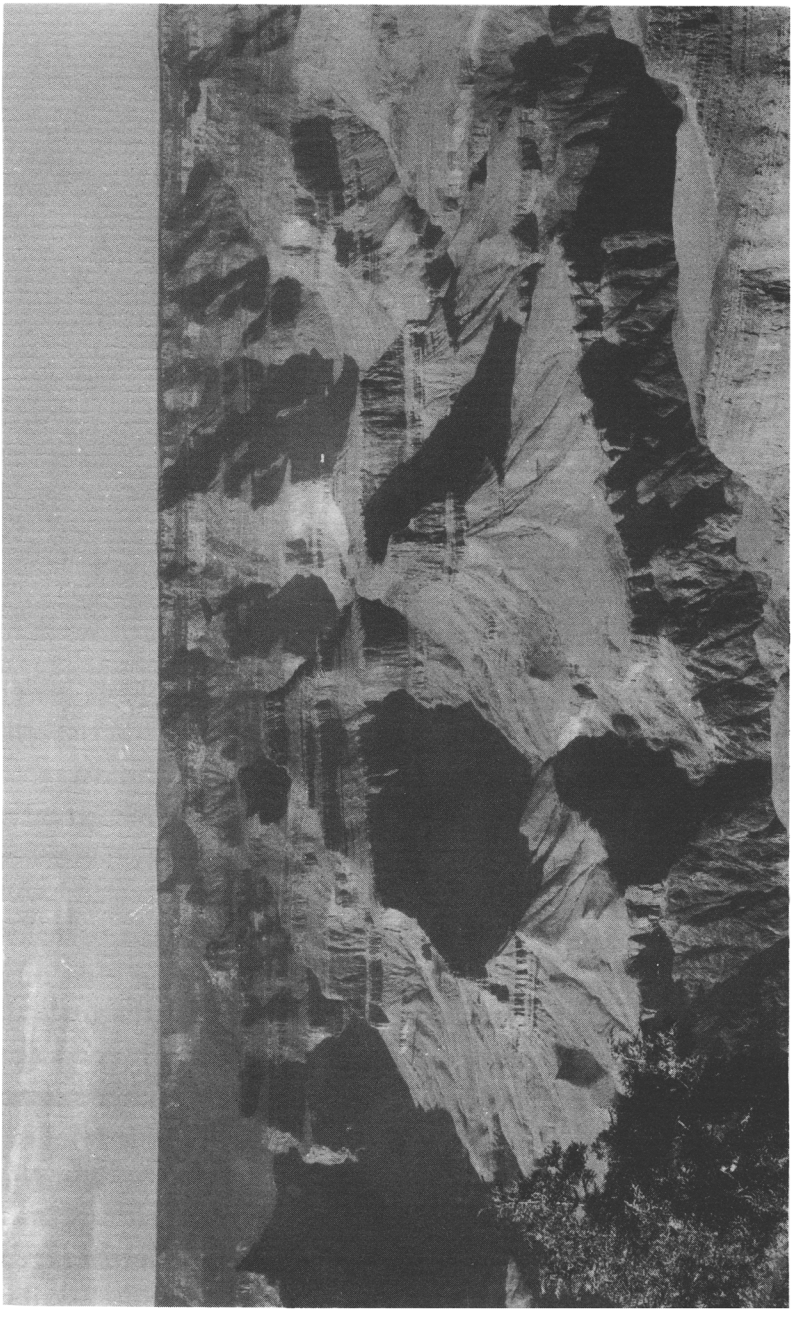

FIGURE 27. Looking north from Artist's View, showing detail of architectural forms.

of hard rock layers giving steep cliffs, with weak layers forming gentle slopes of graceful curvature, completes the architectural illusion which led the entranced beholder to compare these rocky masses with temples, and to give to them the names of Oriental deities. To a beauty of form which ravishes the eye, the temples add a splendor of coloring that makes of the Grand Canyon of the Colorado one of the greatest scenic marvels of the world.

The Canyon is a semi-desert, and the geologic structure is not concealed by any appreciable covering of vegetation. Lights and shadows bring out in bold relief the cliffs and benches, buttes and temples, carved by Nature's architect in the horizontal rocks (Fig. 27); while deeper down one gets a suggestion of the more sombre colors and irregular forms of the ancient crystallines of the old mountain foundation. If we descend to the river we are wholly in the crystallines at this point, and catch but glimpses of the horizontal rocks above. The river itself is a torrent of liquid red mud, hurrying onward in its great task of carrying the high plateaus into the depths of the sea.

Now come with me to the most significant spot in the whole length of the titanic chasm (Fig. 28). It is the point of the wedge of inclined sedimentary rock (compare Fig. 11), developed early in the history of the region. To the west are the ancient crystallines of the old mountain system. Bevelling across these mountain structures is the first erosion surface, developed by long-continued stream action. Above this inclined plane lies the wedge of ancient sedimentary rocks which first buried it and were then, with it, tilted toward the east. Bevelling horizontally across both the older crystallines at the west and the tilted sedimentaries at the east, is the next erosion plane, clearly marked in nature. Above it come the horizontal beds of the main plateau mass.

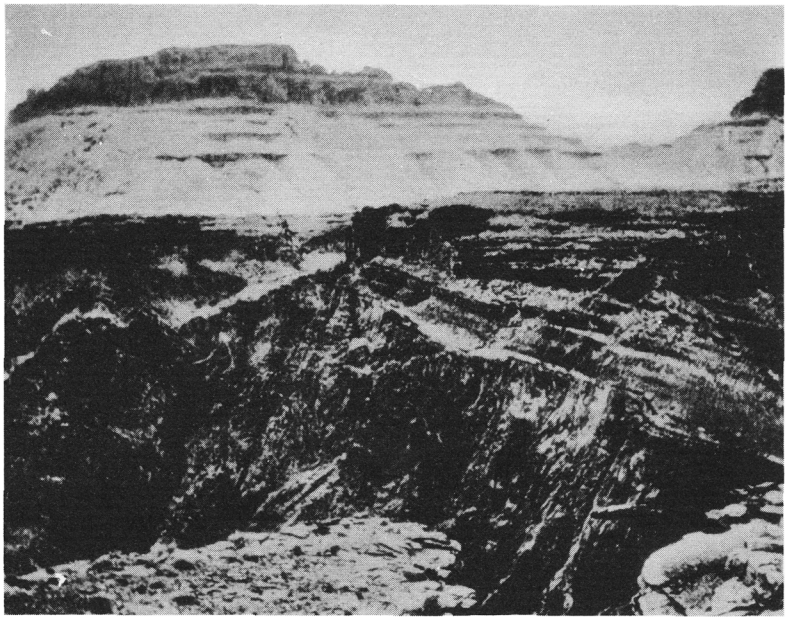

FIGURE 28. The place where three scenic provinces meet: the point of the wedge of inclined rocks (Algonkian wedge). Above are the horizontal plateau rocks; right centre, the inclined rocks of the wedge; left and below, the ancient crystallines. *Photo by H. W. Shimer.*

In this structure we find the key to the three principal types of scenery in the Canyon itself: the scenery of the narrow trench in the crystallines, commonly called the "Granite Gorge"; the scenery of the more open canyon in the tilted weaker rocks of the sedimentary wedge; and the architectural scenery of the buttes and temples developed in the horizontal beds of the upper walls of the canyon. In this one view all three scenic provinces meet. Is it not just, therefore, to call this the most impressive and significant point in all the great abyss?

To see how striking is the contrast between the different types of canyon scenery, due to the different geological conditions which control them, let us take our stand near this

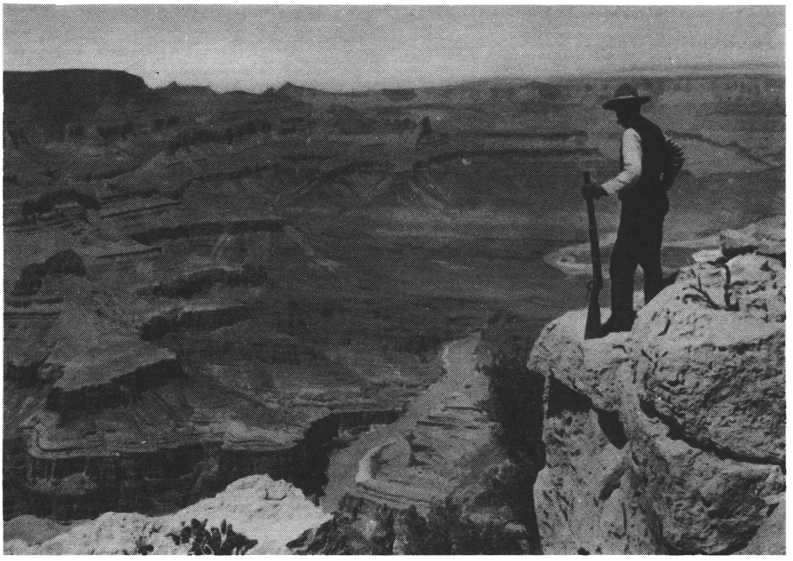

FIGURE 29. Looking eastward into part of the Grand Canyon eroded in the inclined beds of the wedge below, with the horizontal layers of the plateau above. *Photo copyright by Underwood and Underwood.*

remarkable point. First we turn eastward, where the river has opened its course in the inclined beds of the sedimentary wedge (Fig. 29) and view the superbly colored landscape in which the tilted rocks, sloping downward to disappear under the river one after the other, give a character to the scenery not found elsewhere in the Canyon. Bevelling across the tilted wedge the later erosion surface is plainly shown, while above it the architectural forms of the horizontal beds dominate the scene. Now let us turn and face toward the west (frontispiece) : instantly we are in another world! The gloomy depths of the Granite Gorge have nothing in common with the brighter vistas of the tilted wedge. There breadth and brilliancy amaze the eye; here depth and grandeur stupefy the mind.

One would gladly rest with the spell of this mighty con-

trast dominating the emotions. But beyond the canyon to the north there is a last remarkable element in the scenery of the Grand Canyon District, and we must give to it the remainder of our time. We ascend the northern wall of the Canyon, and cross northward over the sagebrush-covered Kanab block, which we saw earlier on our east-west journey. Along the northern horizon stretch cliffs of barren rock. At their base, but well in front, we glimpse a low scarp in grey and chocolate colors, which is the first and lowest step of the giant stairway leading up to the High Plateaus of Utah.

Mounting these Shinarump Cliffs we come in full view of the second step, the richly colored Vermilion Cliffs (Fig. 30). We are still in the sagebrush country, and the face of the grand escarpment is a barren desert. So vivid is its coloring that when the clouds hang low they are suffused

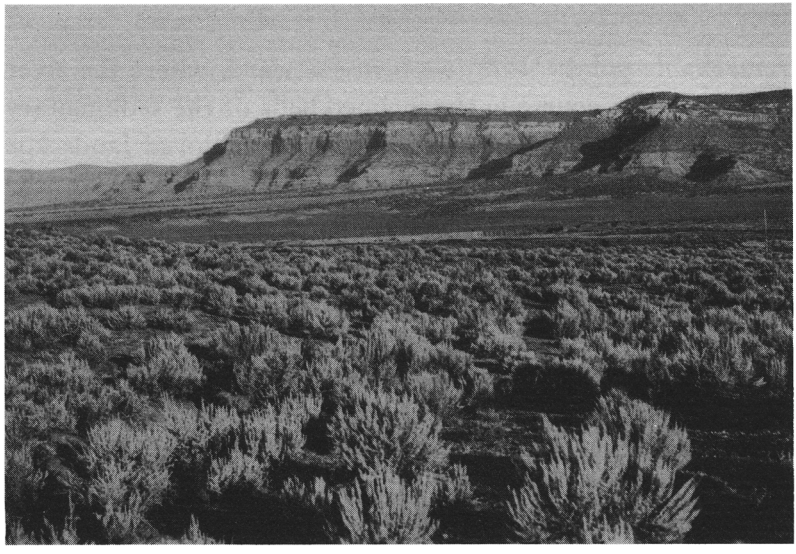

FIGURE 30. Vermilion Cliffs near Kanab, Utah. One of the erosion escarpments of the High Plateaus, which bound the Grand Canyon district on the north.

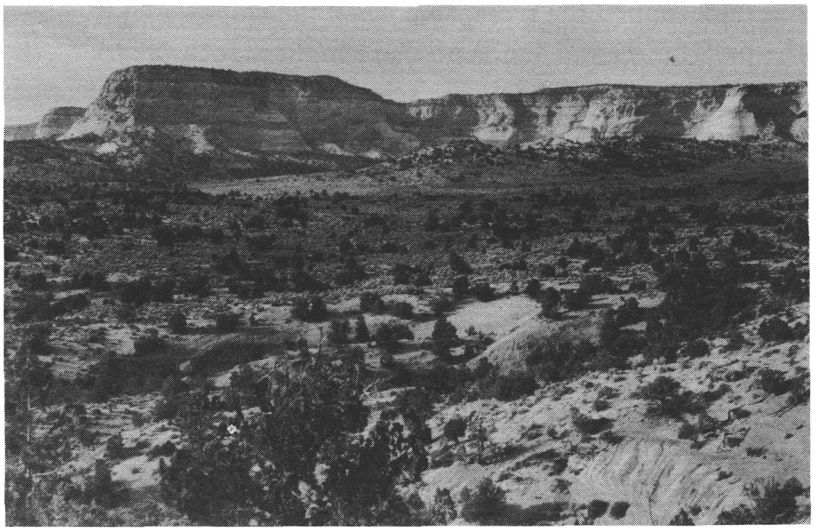

FIGURE 31. White Cliffs north of Kanab, Utah. Another of the great erosion scarps bounding the Grand Canyon district on the north.

with a ruddy glow of reflected light, as if from some great fire; and it seems most appropriate that the cliffs should bear the name, not of some person or locality, but of the color which adds so greatly to their scenic beauty.

A thousand feet we rise to reach the summit of the Vermilion Cliffs; and then the third giant step, appropriately named the White Cliffs (Fig. 31), bursts suddenly upon the view. Composed of pure sandstone, fine grained like sugar and equally white, the great escarpment towers high and forbidding along the northern horizon. The whole aspect of the country has changed, and the presence of cedars and junipers records the greater elevation.

Once again we rise a thousand feet or more, pass northward beyond the White Cliffs, and see in the distance the last giant upward step, the Pink Cliffs. It is not so steep as the southern scarps, and forests cover much of its sloping face. But here and there the headward growth of streams

has undermined the trees, steepened the slopes, and revealed the pink marls and sands of these highest rock layers of the Grand Canyon District. It seems as though the last uplift of the plateau, which caused the main river to cut the Canyon, permitted the side streams to steepen and freshen the Shinarump, Vermilion, and White Cliffs; but that the effect of the uplift has just reached the more distant Pink Cliffs, where the work of steepening and freshening has only begun. There is thus a significance in the unusual appearance of the Pink Cliffs which gives to their different scenery an added interest.

On the summit of the Pink Cliffs, two miles above sea level, you stand at the northern border of the Grand Canyon District, on the threshold of the High Plateaus of Utah. From this point of vantage, give one last look backward, far away to the south, where the Grand Canyon of the Colorado is cutting its way into the earth's crust, and consider the significance of the view. Ceaselessly, throughout the ages, the tiny thread of water in the depths of that abyss is carrying to the distant ocean the débris eroded from the plateau walls. Not until the mighty chasm has been deepened and widened, not until the stream and its branches have demolished the plateau rocks, undermined the volcanoes, obliterated the great escarpments, and swept the entire mass into the sea, will the great work, of which we see only the beginning, be completed.

In how many millions of years? We know not. But this we do know: that however long this erosion history may endure, at least three times in the past, as revealed by the structures exposed in the canyon walls, a work of erosion equally vast has been carried to completion, giving the erosion planes revealed in the canyon walls. How tiny is the span of human life; how infinitely insignificant the whole

of human history, compared with such stupefying periods of time. "What is man, that thou art mindful of him? And the son of man, that thou visitest him?"

This is the message of the Grand Canyon to him who meditates upon its significance.

Somes Sound, a fjord-like embayment of the sea entering the mountains of Mount Desert Island, Maine. *Courtesy of Acadia National Park.*